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King-Wilson

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(54) **ASSESSING THREAT TO AT LEAST ONE COMPUTER NETWORK**

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This patent is subject to a terminal disclaimer.

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H04L 29/06 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 63/1416*** (2013.01); ***G06Q 20/4016*** (2013.01); ***H04L 63/1425*** (2013.01)

(58) **Field of Classification Search**
CPC ... G06F 21/56; G06F 11/34; H04L 29/06877; H04L 29/06904; H04L 29/06897; H04L 29/06918; H04L 63/14; H04L 63/1425; H04L 63/1433; H04L 63/145
See application file for complete search history.

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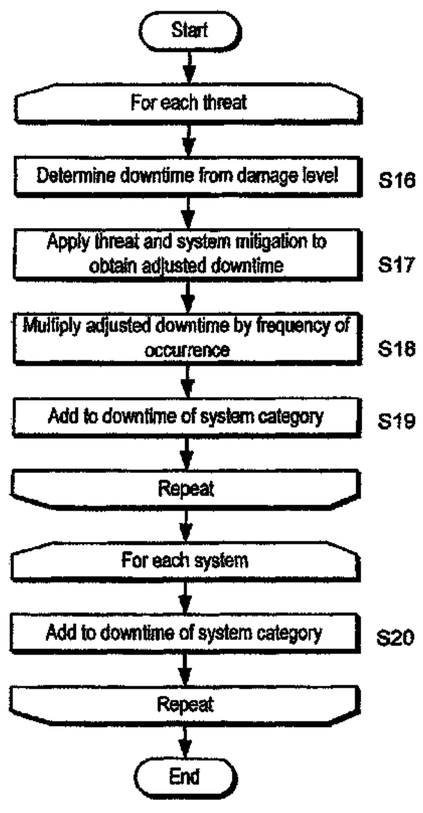
Primary Examiner — Linglan Edwards
Assistant Examiner — Gary Gracia

(57) **ABSTRACT**

Apparatus for assessing threat to at least one computer network in which a plurality of systems ($\mathbf{30}_1$, $\mathbf{30}_2$, $\mathbf{30}_3$, $\mathbf{30}_4$, $\mathbf{30}_5$, . . . $\mathbf{30}_n$) operate is configured to determine predicted threat activity (**13**), to determine expected downtime of each system in dependence upon said predicted threat activity, to determine loss ($\mathbf{12}_A$, $\mathbf{12}_B$, $\mathbf{12}_C$, $\mathbf{12}_D$, $\mathbf{12}_E$, . . . , $\mathbf{12}_m$) for each of a plurality of operational processes ($\mathbf{31}_A$, $\mathbf{31}_B$, $\mathbf{31}_C$, $\mathbf{31}_D$, $\mathbf{31}_E$, . . . $\mathbf{31}_m$ dependent on the downtimes of the systems, to add losses for the plurality of processes so as to obtain a combined loss ($\mathbf{12}_{SUM}$) arising from the threat activity.

16 Claims, 8 Drawing Sheets



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G06Q 20/40 (2012.01)
G06F 12/14 (2006.01)

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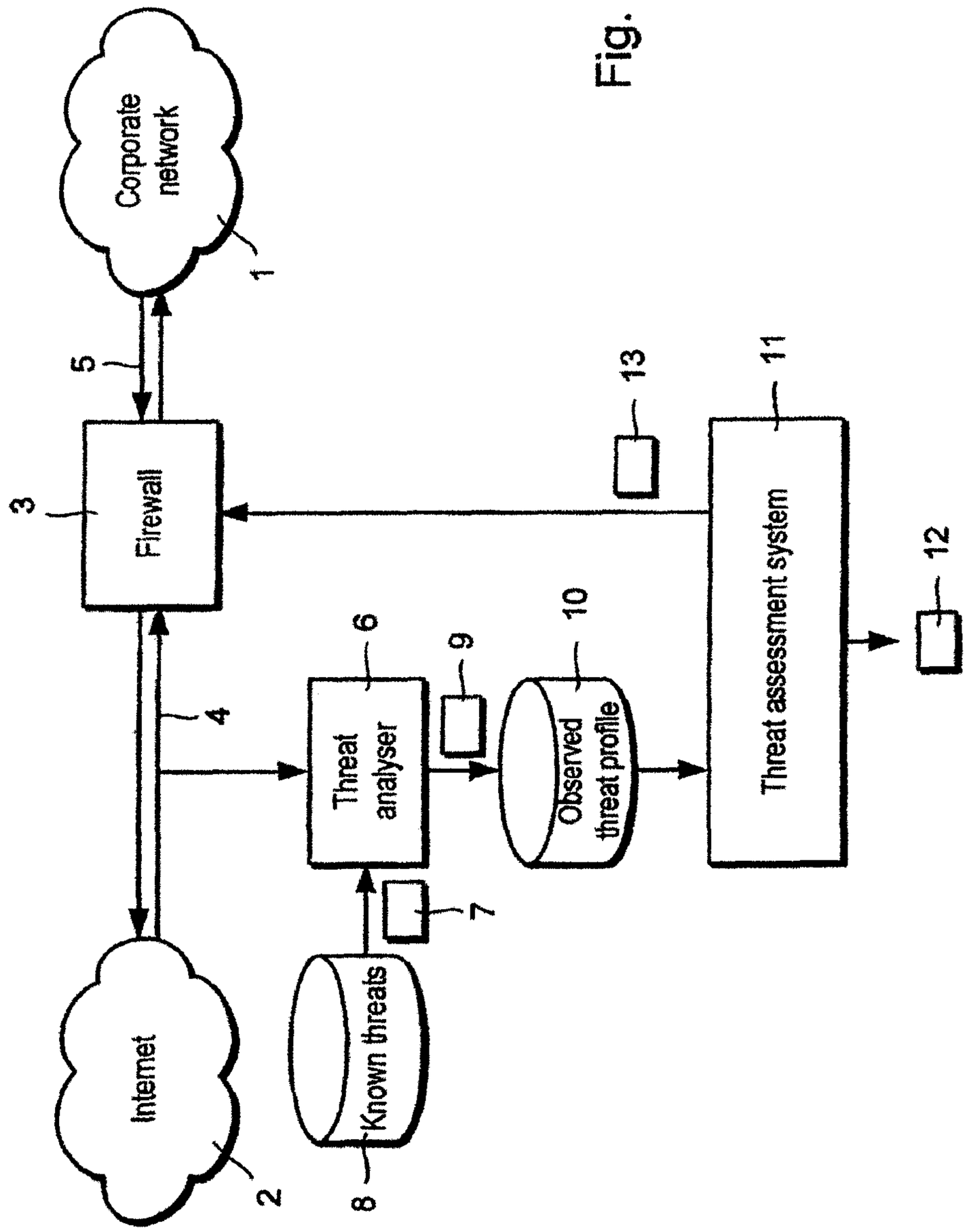
Corporate network
1
5
Firewall
3
4
Internet
2
Threat analyser
6
9
7
Known threats
8
10
Observed threat profile
13
11
Threat assessment system
12

Fig. 1

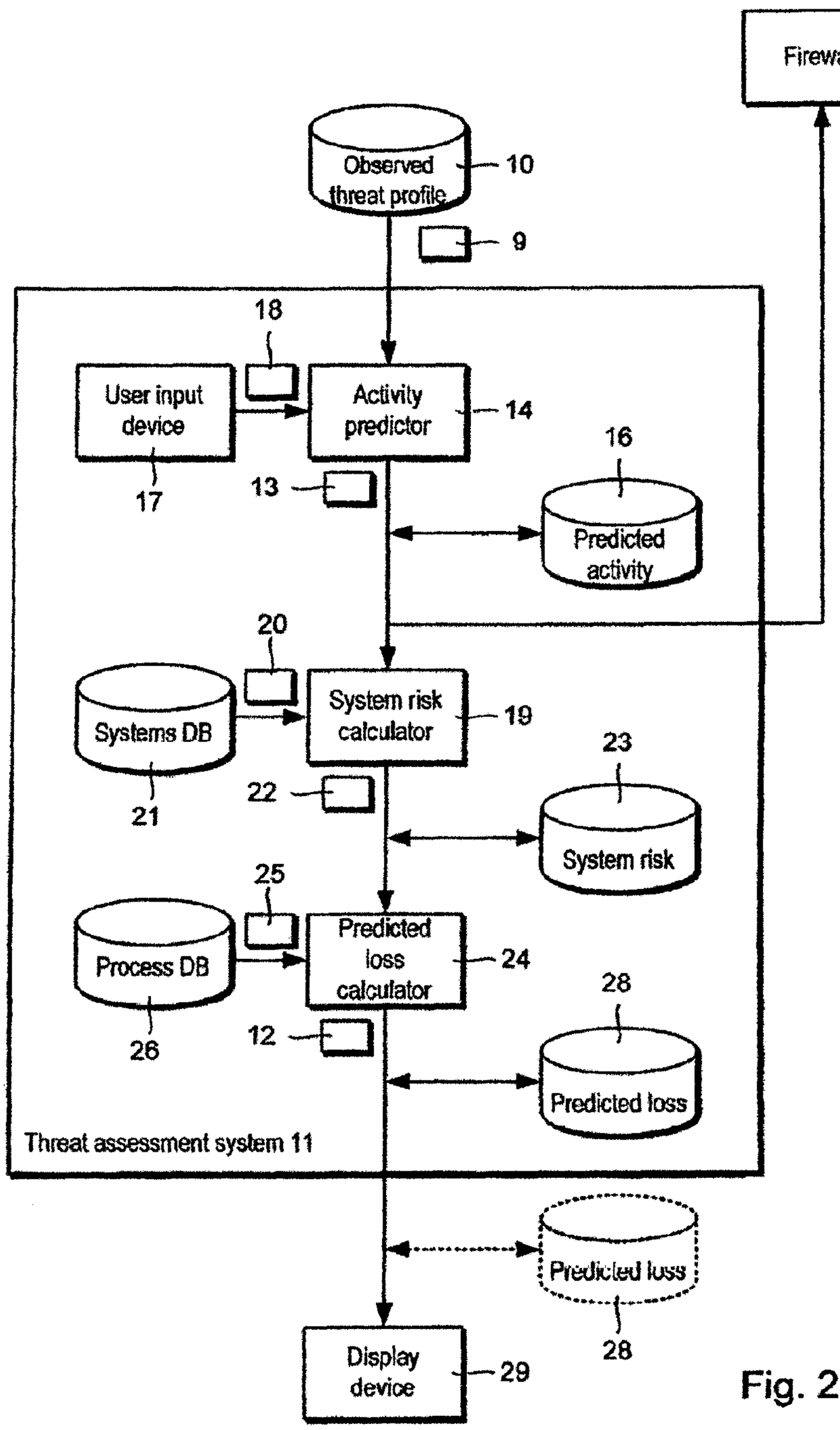
Firewall
3
Observed threat profile
10
9
18
User input device
17
Activity predictor
14
13
16
Predicted activity
20
Systems DB
21
System risk calculator
19
22
23
System risk
25
Process DB
26
Predicted loss calculator
24
12
28
Predicted loss
Threat assessment system 11
Predicted loss
28
Display device
29

Fig. 2

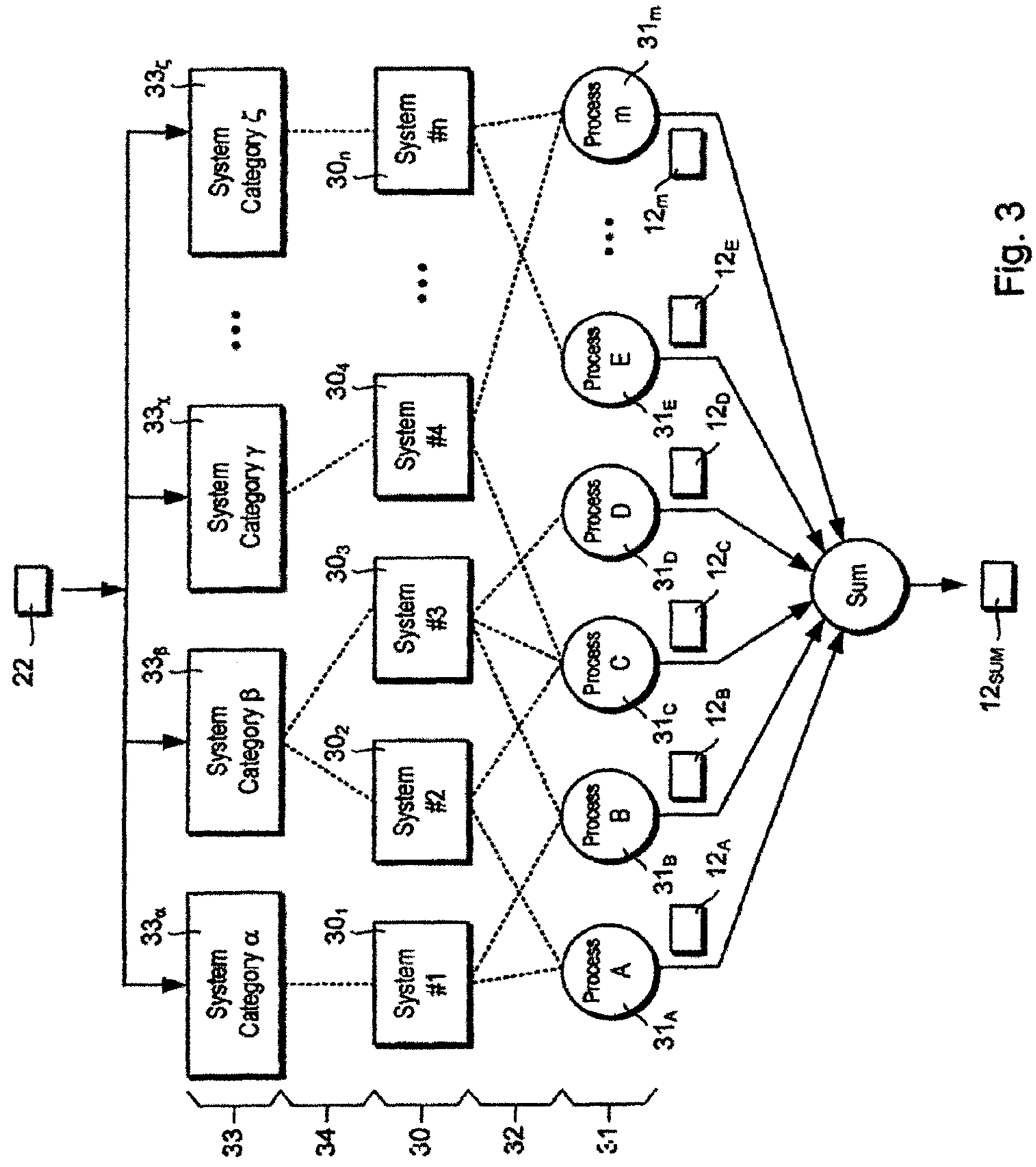
22
33α
System Category α
33β
System Category β
33χ
System Category χ
33δ
System Category δ
30₁
System #1
30₂
System #2
30₃
System #3
30₄
System #4
30n
System #n
31A
Process A
31B
Process B
31C
Process C
31D
Process D
31E
Process E
31m
Process m
12A
12B
12C
12D
12E
12m
Sum
12SUM
33
34
30
32
31

Fig. 3

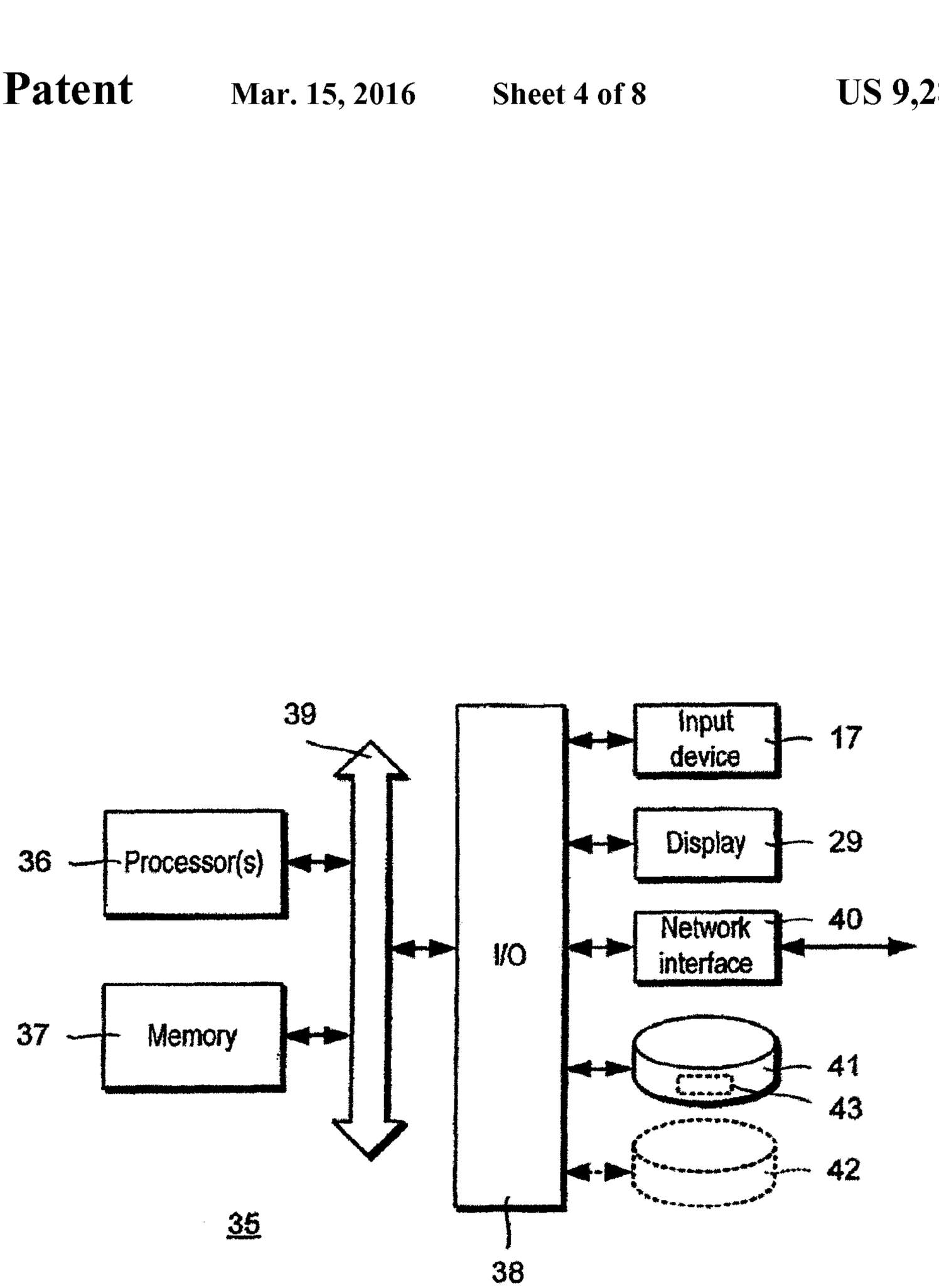
39
36
Processor(s)
37
Memory
I/O
Input device
17
Display
29
Network interface
40
41
43
42
35
38

Fig. 4

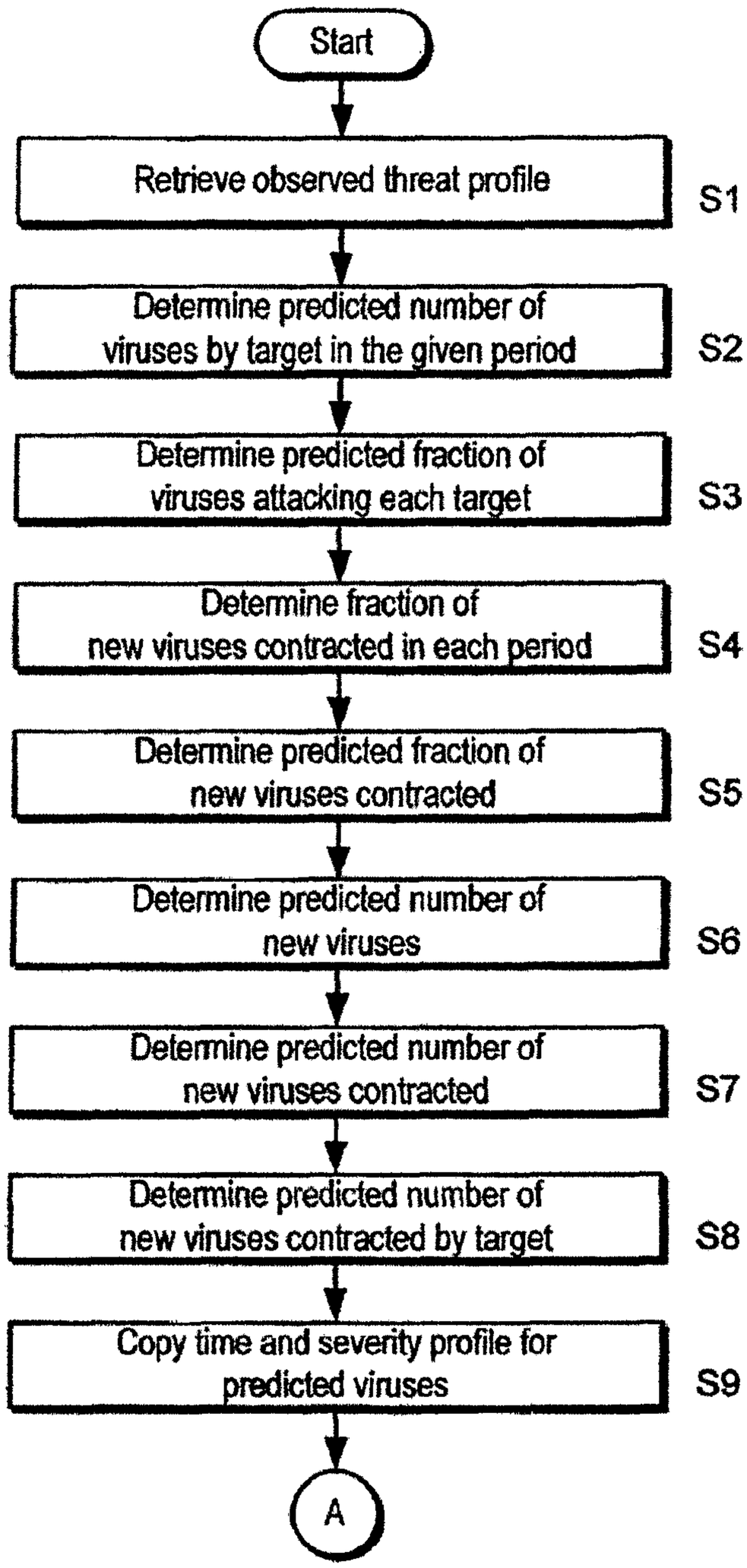
Start
Retrieve observed threat profile
S1
Determine predicted number of viruses by target in the given period
S2
Determine predicted fraction of viruses attacking each target
S3
Determine fraction of new viruses contracted in each period
S4
Determine predicted fraction of new viruses contracted
S5
Determine predicted number of new viruses
S6
Determine predicted number of new viruses contracted
S7
Determine predicted number of new viruses contracted by target
S8
Copy time and severity profile for predicted viruses
S9
A

Fig. 5A

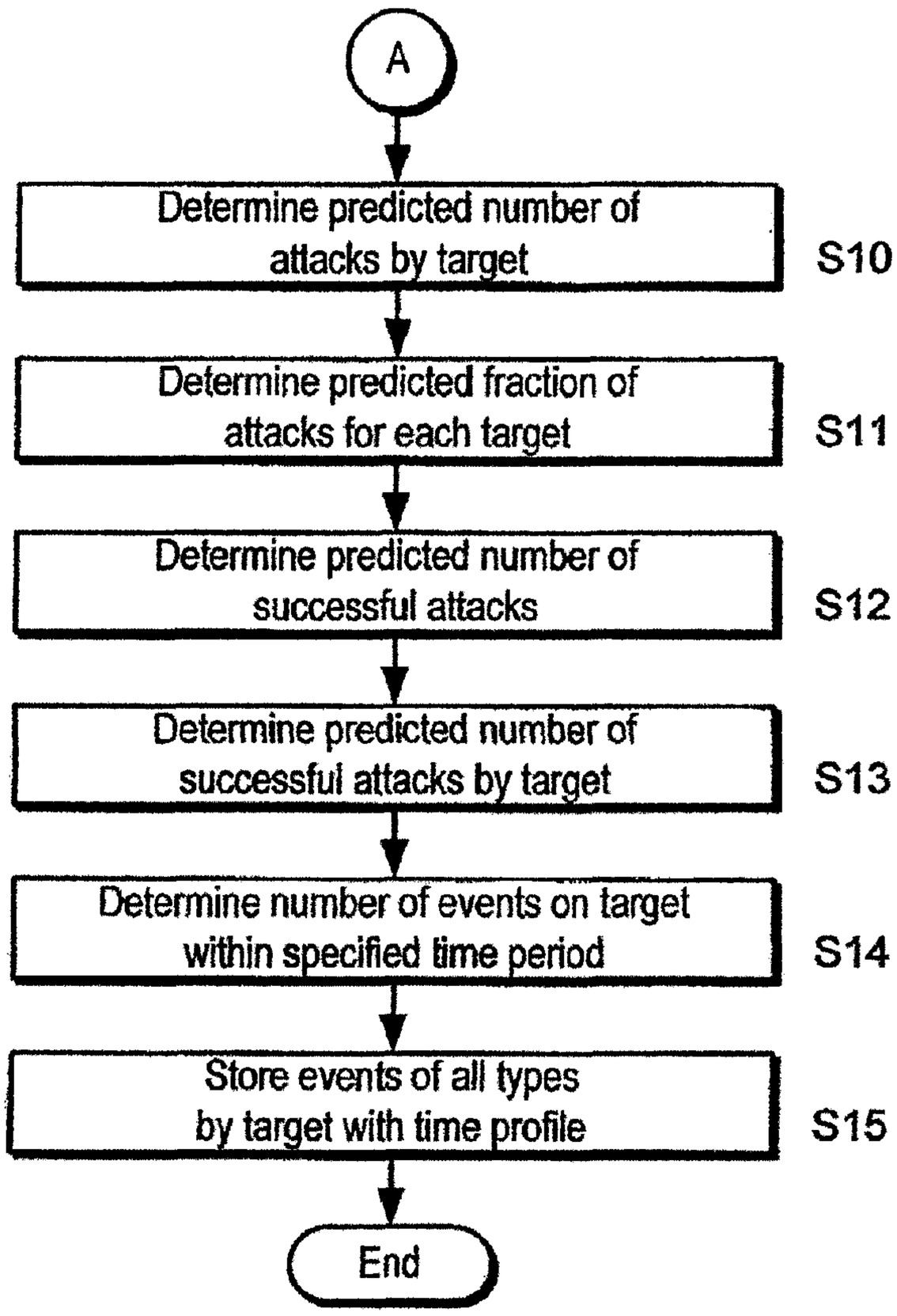
A
Determine predicted number of attacks by target
S10
Determine predicted fraction of attacks for each target
S11
Determine predicted number of successful attacks
S12
Determine predicted number of successful attacks by target
S13
Determine number of events on target within specified time period
S14
Store events of all types by target with time profile
S15
End

Fig. 5B

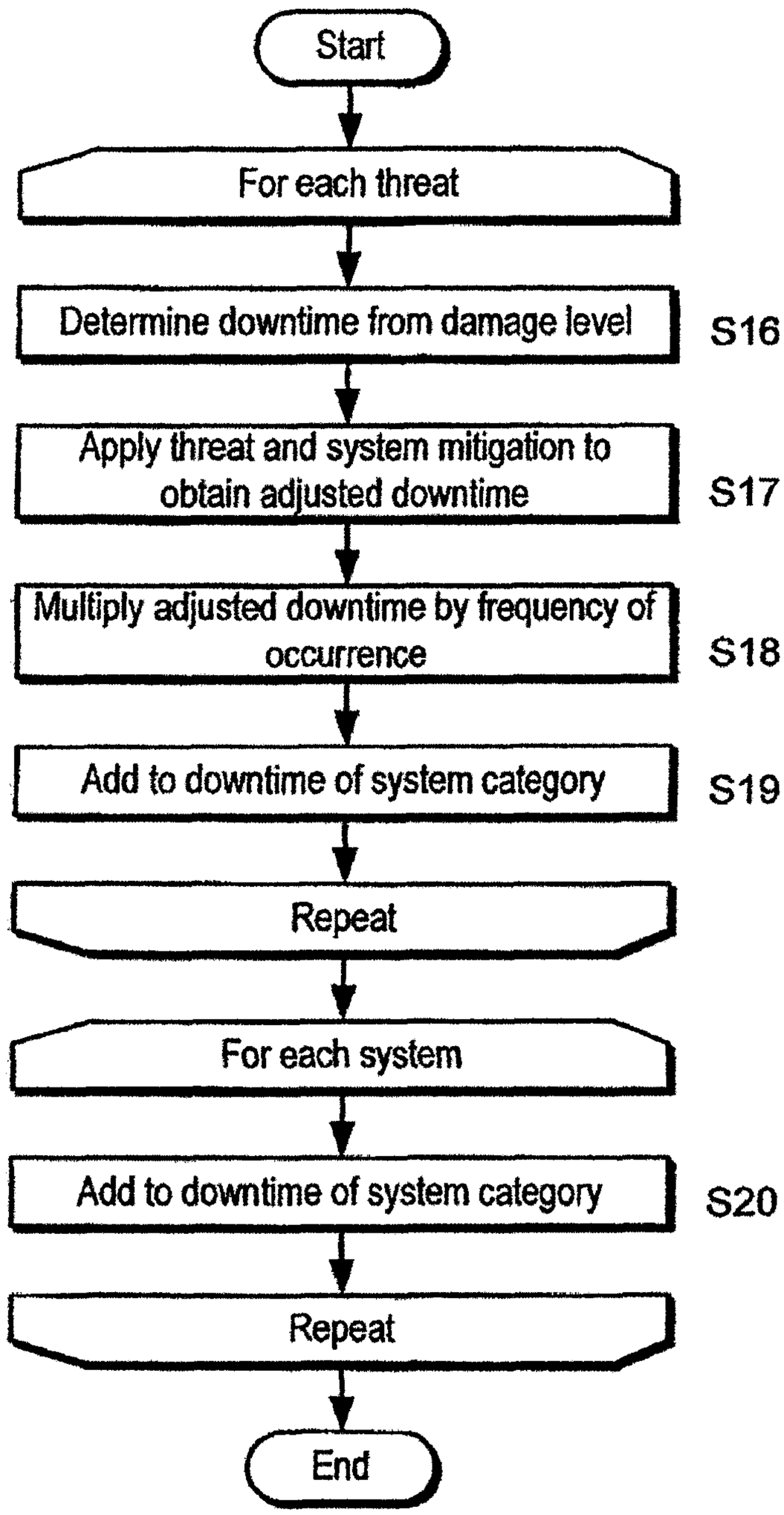
Start
For each threat
Determine downtime from damage level
S16
Apply threat and system mitigation to obtain adjusted downtime
S17
Multiply adjusted downtime by frequency of occurrence
S18
Add to downtime of system category
S19
Repeat
For each system
Add to downtime of system category
S20
Repeat
End

Fig. 6

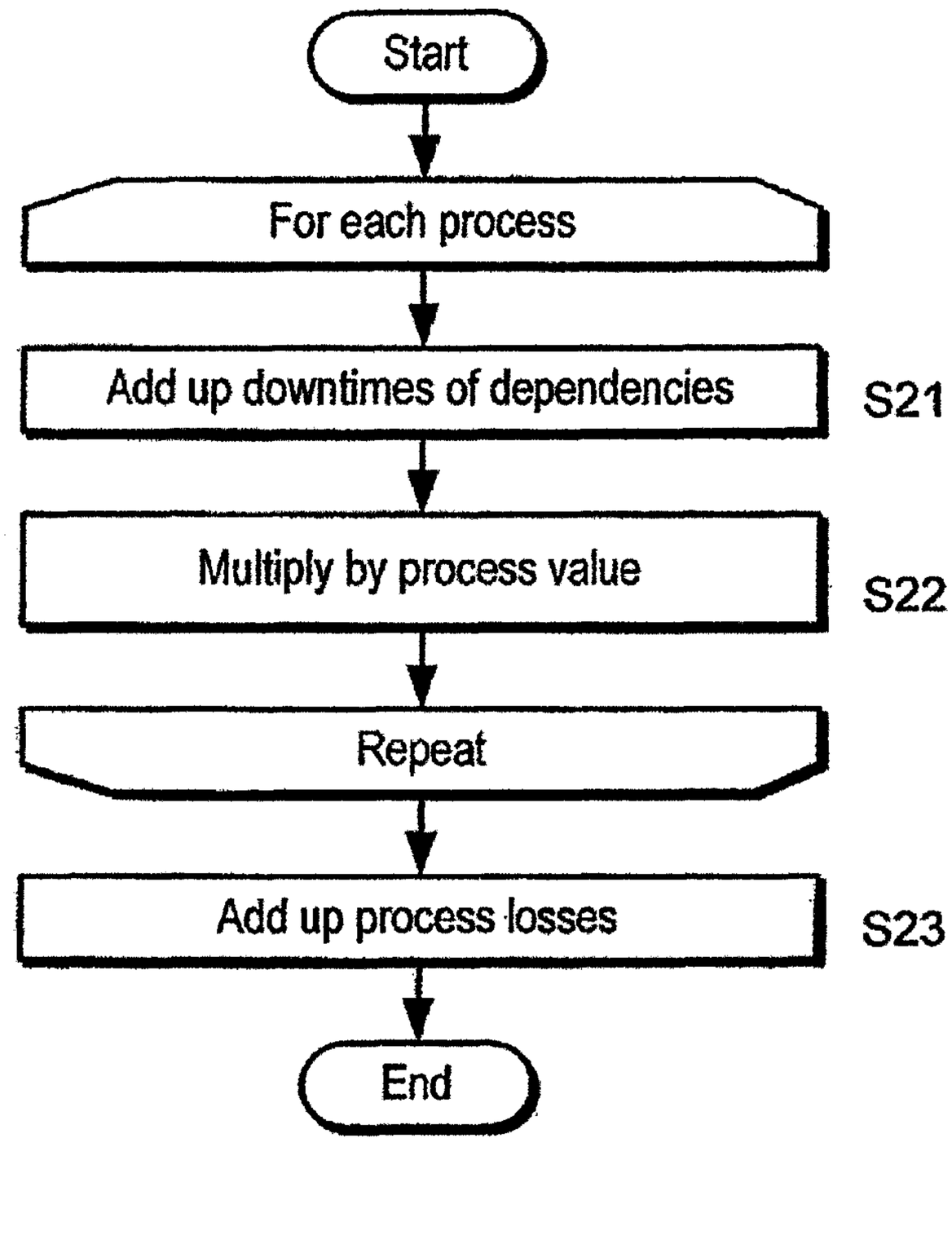
Start
For each process
Add up downtimes of dependencies
S21
Multiply by process value
S22
Repeat
Add up process losses
S23
End

Fig. 7

ASSESSING THREAT TO AT LEAST ONE COMPUTER NETWORK

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation of application Ser. No. 12/811,208, Filed Sep. 1, 2010, granted Apr. 28, 2015, the entire content of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to apparatus for and a method of assessing threat to at least one computer network.

BACKGROUND ART

Large organizations, such as international banks and other financial institutions, rely heavily on their computer systems to carry out their business operations. Increasingly, organizations are connecting their networks to public networks, such as the Internet, to allow them to communicate with their customers and other organizations. However, in doing so, they open up their networks to a wider range and greater number of electronic threats, such as computer viruses, Trojan horses, computer worms, hacking and denial-of-service attacks.

To respond to these forms of threat, organizations can implement procedures, tools and countermeasures for providing network security. For example, they can install intrusion detection and prevention systems to protect their network. However, even if these security systems are properly managed and well maintained, their network may still be vulnerable to threat. Furthermore, their network may also be vulnerable to other, non-electronic forms of threat, such as fire, flood or terrorism.

The present invention seeks to provide apparatus for and a method of assessing threat to a computer network or computer networks.

SUMMARY OF THE INVENTION

According to the present invention there is provided apparatus for assessing threat to at least one computer network in which a plurality of systems operate, the apparatus configured to determine predicted threat activity, to determine expected downtime of each system in dependence upon said predicted threat activity, to determine loss for each of a plurality of operational processes dependent on the downtimes of the systems, to add losses for the plurality of processes so as to obtain a combined loss arising from the threat activity.

The apparatus may comprise a first module configured to determine the predicted threat activity, a second module configured to determine the expected downtime of each system and a third module configured to determine the loss for each of a plurality of operational processes. The third module may be configured to add the losses for the plurality of processes.

The apparatus may be configured to store at least one of the losses and the combined loss in a storage device. The apparatus may be configured to display at least one of the losses and the combined loss on a display device.

The apparatus may be further configured to output the predicted threat activity to a firewall.

The loss may be value at risk.

The apparatus may be configured to retrieve a list of observed threats and to determine the predicted threat activity based upon the list of observed threats.

The observed list of threats may include, for each threat, information identifying at least one system. The observed list of threats may include, for each threat, information identifying frequency of occurrence of the threat. The frequency of occurrence of the threat may include at least one period of time and corresponding frequency of occurrence for the at least one period of time.

The plurality of systems may include a plurality of software systems

According to a second aspect of the present invention there is provided a method of assessing threat to at least one computer network in which a plurality of system operate, the method comprising determining predicted threat activity, determining expected downtime of each system in dependence upon said predicted threat activity, determining loss for each of a plurality of operational processes dependent on the downtimes of the systems, adding losses for the plurality of processes to obtain a combined loss arising from the threat activity.

The method may further comprise storing at least one of the losses and combined loss in a storage device. The method may further comprise displaying at least one of the losses and combined loss on a display device.

According to a third aspect of the present invention there is provided a computer program, which, when executed by a computer system, causes the computer system to perform the method.

According to a fourth aspect of the present invention there is provided a computer readable medium storing the computer program.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings in which:

FIG. **1** is a schematic diagram of two computer networks connected via a firewall, a system for analyzing network traffic and a system for assessing threat in one of the computer networks;

FIG. **2** is a detailed schematic diagram of the system for assessing threat to a computer network shown in FIG. **1**;

FIG. **3** illustrates calculation of loss arising from predicted threat;

FIG. **4** is a schematic block diagram of a computer system providing threat assessment;

FIG. **5** is a process flow diagram of a method of predicting threat activity;

FIG. **6** is a process flow diagram of a method of calculating system risk; and

FIG. **7** is a process flow diagram of a method of calculating predicted loss.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Referring to FIG. **1**, a corporate network **1** is connected to an external network **2**, in this case the Internet, via a firewall **3**. The firewall **3** filters incoming traffic **4** from the Internet and, optionally, outgoing traffic **5**, according to a security policy (not shown). The corporate network **1** may be provided a single, private network. The network **1** need not be a corporate network, but can be a government, academic, military or other form of private network. The network **1** may include a plurality of interconnected networks, for example which are geographically distributed.

The Internet **2** is a source of electronic threat, such as computer viruses (herein referred to simply as "viruses"). Trojan horses ("Trojans"), computer worms ("worms"), hacking and denial-of-service attacks. If a threat enters the corporate network **1** and is not stopped, then it can cause damage within the corporate network **1**. For example, a virus may infect information technology (IT) systems **30** (FIG. **3**) within the corporate network **1** resulting in the loss of one or more operational processes **31** (FIG. **3**), for example a business process, either as a direct result of infection and/or as a result of measures taken to remove the virus from the infected system. Loss can also occur as the result of other forms of attack, such as hacking and denial-of-service attacks.

An IT system may be or include software, such as an operating system, an application or a combination of operating system and application(s). An IT system may be or include hardware, such as server(s), storage, network connections or a combination of one or more hardware elements. As will be explained in more detail later, some types of threat, such as virus, may affect software, and other types of threat, such as fire, may affect hardware and/or software. An IT system can be treated, for the purposes of assessing threats, as a combination of software and hardware.

The degree to which an organization will be affected by a successful attack depends on a number of factors, such as the number of IT systems **30** (FIG. **3**) affected by the attack and the number of operational processes **31** (FIG. **3**) relying on the affected IT systems **30** (FIG. **3**).

If the likelihood of an attack succeeding can be estimated for a number of different threats, then this can be combined with knowledge of the logical structure of IT systems **30** (FIG. **3**) within the network **1** and knowledge of processes **31** (FIG. **3**) dependent on those IT systems **30** (FIG. **3**) to predict, for a given period of time, loss to the organization due to these threats. In some embodiments, the predicted loss is expressed as a value at risk (VAR). However, the prediction may be expressed as any value or figure of merit which characterizes or quantifies loss to the organization arising from operational processes being disabled.

A module **6** (hereinafter referred to as a "threat analyzer") samples incoming traffic **4** and identifies threats using a list **7** of known threats stored in a database **8**. For example, the module **6** may be a computer system running SNORT (for example release 2.6.0.1) available from www.snort.org.

The threat analyzer **6** produces observed threat data **9**, which includes a list of observed threats and their frequency of occurrence, and stores the data **9** in a database **10**.

In some embodiments of the present invention, a system **11** for assessing threat uses models threats to the corporate network **1** so as to predict loss **12** arising from these threats and/or to provide feedback **13** to the firewall **3**.

Each observed threat is defined using an identifier, a name, a description of the threat, a temporal profile specifying frequency of occurrence of the threat, a target (or targets) for the threat and a severity score for the (or each) target.

The identifier (herein the attribute "Threat ID" is used) uniquely identifies a threat.

The Threat ID may be string of up to 100 characters. For example, the Threat ID may be "Win32.Word.B32 m".

The target ("Target") is a system category attacked by the threat. Targets are preferably named in a systematic way. Examples of targets include "Windows.XP" or "Oracle.9i". Targets can be identified at different levels using a format "system.version[-system.version[-system.version]]". For example, if a threat attacks Oracle running on Windows XP, then the target may be specified as "Oracle.9i-Windows.XP".

A system category may depend on other categories. For example, a company may have a system which depends on Windows Server 2003 and another system which depends on Windows XP, i.e. two different system categories. Thus, if a threat attacks more than one category, such as all versions of Windows, this can be handled by introducing a third system category, such as Windows, on which both of the other categories, in this example Windows Server 2003 and Windows XP, depend.

The severity score ("SeverityScore") is a measure of the impact of a successful threat. It is not a measure of the prevalence or exposure to the threat, but rather an indication of the damage that would be caused to the target system. Severity score may also be referred to as "damage level". In this example, the severity score is a value lying in a range between 1 and 10. For example, a value of 1 can represent trivial impact and a value of 10 may represent a catastrophic effect. However, the severity score may be defined as "low", "medium", "high" or "critical".

The temporal profile is used to describe frequency of occurrence of a threat because loss caused by system downtime may vary according to the time of the week. The temporal profile may be visible to and/or editable by a user for some types of threat, such as physical threats, and may be implicit and/or fixed for other types of threat, such as that defined in SNORT data.

The profile is expressed as a sequence of elements, each of which has a time block and a count of the observed occurrences of the threat during the block. Threat occurrences are preferably aggregated as far as possible to provide a simple profile whilst remaining consistent with recorded instances. A more complex profile can be used if the simple profile significantly deviates from recorded instances. For example, if a threat is observed only a very small number of times, then it is appropriate to specify a uniform time profile. However, if a different threat is observed many times and always, for example, on a Monday morning, then a more complex profile reflecting the actual distribution may be used.

Herein the temporal profile is defined in terms of day (attribute "Day"), period of day ("From", "To") and frequency ("Count").

Time blocks need not be same for different threats, although, for any given threat, blocks should do not overlap. If a part of a week is not covered by a block, threat occurrence is assumed to be zero.

The observed threat data is stored as a single file in Extensible Markup Language (XML) format encoded using 8-bit Unicode Transformation Format (UTF) as shown in the following simple example:

```
<?xml version="1.0" encoding="utf-8" ?>
<AssessmentSystem Version ="1">
<ObservedThreats ObservationStart="2006-07-31T00:00:00"
ObservationEnd="2006-08-07T00:00:00">
<Threat ID="Win32.Worm.B32m" Target="Windows.XP"
SeveritySeore="4">
<Observation From="00:00:00" To ="12:00:00" Count="8"/>
<Observation From="12:00:00" To="00:00:00" Count="1"/>
</Threat>
<Threat ID="Linux.Trojan.A12s" Target="Oracle.9i" SeverityScore="6">
<Observation Day="Monday" Count="50"/>
<Observation Day="Tuesday Wednesday" Count="23"/>
<Observation Day="Thursday Friday Saturday" Count="11"/>
<Observation Day="Sunday" Count="0"/>
</Threat>
<Threat ID="DenialOfService" Target="IIS" SeverityScore="2">
<Observation Day="Sunday" From="00:00:00" To="08:00:00"
Count="1154"/>
```

-continued

```
<Observation Day="Sunday" From="08:00:00" To="16:30:00"
Count="237"/>
<Observation Day="Monday" To="12:00:00" Count="350"/>
<!--From is 00:00:00-->
<Observation Day="Monday" From="12:00:00" Count="208"/>
<!--To is 00:00:00-->
<Observation Day="Tuesday Wednesday Thursday Friday Saturday"
Count="2134"/>
</Threat>
</ObservedThreats>
</ AssessmentSystem >
```

In the example just given, three different types of observed threat are specified, namely a virus "Win32.WormB32 m" a Trojan "Linux.Trojan.A12s" and a denial-of-service attack "DenialOfService". However, it will be appreciated that there may be many more observed threats, e.g. tens or hundreds of thousands of threats or more.

Referring to FIG. **2**, the threat assessment system **11** includes a first module **14** (hereinafter referred to as an "activity predictor") for predicting threat activity affecting the corporate network **1**.

The activity predictor **14** receives the observed threat data **9** from the database **10**, for example by retrieving the data automatically or in response to user instruction, extrapolates future event frequency and produces a profile **13** of predicted threat activity, which includes a list of predicted threats and their expected frequency of occurrence. The predicted threat activity profile **13** may be stored in a database **16**.

Event frequency can be extrapolated from the historical data using a variety of editable factors which can be based upon advice from security consultants, political factors and so on.

Each predicted threat is defined using an identifier, a name, a description, a frequency of occurrence, a category (or categories) of system attacked and a corresponding damage level for each system.

A user, via input device **17**, can manually add information **18** about other electronic and non-electronic forms of threat so that it can be added to the predicted threat activity profile **13**.

Non-electronic forms of threat include, for example, fire, flood and terrorism attack. Information about non-electronic forms of attack is arranged in a similar way to information about electronic forms of threat and include, for each threat, an identifier, a name, a description and frequency of occurrence, categories of system attacked and corresponding damage levels.

The user can also provide or edit information about threat. For example, they can specify data regarding, extrapolation factors, the IT systems subject to attack, such as its identity, name and category identity, systems categories, such as its identity and name, operational processes, such as its identity, name and value, and process dependencies, such as process identity, system identity, dependency description and dependency level.

As shown in FIG. **2**, the predicted threat activity profile **13** can be fed back to the firewall **3** to tune its operation.

The threat assessment system **11** includes a second module **19** (hereinafter referred to as a "system risk calculator") for calculating system risk.

The system risk calculator **19** receives the predicted threat activity profile **13** (either from the activity predictor **14** or the database **16**) and information **20** about the IT systems **30** (FIG. **3**) and the categories to which they belong from a systems database **21** and produces a risk profile **22** to the systems **30** (FIG. **3**) in terms of predicted average downtime over a given period, usually specified to be a year. The risk **22** can be stored in database **23**.

Each IT system **30** (FIG. **3**) is defined by identity and a name. System categories, i.e. targets, may include operating systems, applications and server location.

An IT system may be defined in terms of physical location. This may be used to identify threats to some types of threat, such as fire, flooding, terrorism, power loss and so on.

The system **11** includes a third module **24** (hereinafter referred to as a "predicted loss calculator") for predicting the loss to the organization.

The predicted loss calculator **24** receives the system risk **22** and data **25** listing operational processes from a database **26**, then predicts the loss for each operational process, aggregates the results for each process and outputs predicted loss data **12**. The predicted loss data **12** may be stored in database **28** and/or output on display device **29**.

Each process is defined by identity and a name, value in terms of the cost of downtime. The dependency of each process on an underlying IT system is defined by process identity, system identity, dependency description and dependency level.

Referring also to FIG. **3**, the predicted loss calculator **24** considers the system risk **22** for the IT systems **30**, $\mathbf{30}_1$, $\mathbf{30}_2$, $\mathbf{30}_3$, $\mathbf{30}_4$, . . . , $\mathbf{30}_n$ on which each process **31**, $\mathbf{31}_A$, $\mathbf{31}_B$, $\mathbf{31}_C$, $\mathbf{31}_D$, $\mathbf{31}_E$, . . . , $\mathbf{31}_m$, depends via dependencies **32** and the value of the process and aggregates values $\mathbf{12}_A$, $\mathbf{12}_B$, $\mathbf{12}_C$, $\mathbf{12}_D$, $\mathbf{12}_E$, . . . , $\mathbf{12}_m$, for each process so as to produce a value $\mathbf{12}_{SUM}$ for all processes. The predicted loss calculator **24** applies the system risk **22** to system categories **33**, $\mathbf{33}_\alpha$, $\mathbf{33}_\beta$, $\mathbf{33}_\gamma$, . . . , $\mathbf{33}_\zeta$ which are related to the systems **30**, $\mathbf{30}_1$, $\mathbf{30}_2$, $\mathbf{30}_3$, $\mathbf{30}_4$, . . . , $\mathbf{30}_n$ by dependencies **34** and the considers how the risk affects each IT system **30**, $\mathbf{30}_1$, $\mathbf{30}_2$, $\mathbf{30}_3$, $\mathbf{30}_4$, . . . , $\mathbf{30}_n$.

In FIG. **3**, only one level or layer of system category **33** is shown for clarity. However, as will be explained in more detail, there may be additional levels of system category **33** such that one or more system categories **33** in a lower level may depend on a system category in a higher level. Thus, a system **30** may depend on one or more system categories **33**, which may arranged in one or more layers.

For example, a system category **33** in a higher level may be Windows and system categories **33** in a lower level may be Windows Server 2003 and Windows XP. A system **30** may be a corporate server which depends on Windows Server 2003 and another system **30** could be desktop computer which depends on Windows XP.

System categories **33** may be omitted and so threats to systems **30** may be considered directly.

The threat assessment system **11** can output a report of the predicted loss, e.g. an aggregate value at risk, to the organization for each process in terms of process name, estimated annual downtime and predicted loss. For example, the report can be shown on the display device **29**, for example, as a bar chart of predicted loss for each process and can be exported as a database file, such as an Microsoft® Excel® file (e.g., with an ".xls" extension) or in eXtensible Markup Language file, (e.g., with an ".xml" extension).

Referring to FIG. **4**, the threat assessment system **11** (FIG. **2**) is implemented in software on a computer system **35** running an operating system, such as Windows, Linux or Solaris. The computer system **35** includes at least one processor **36**, memory **37** and an input/output (I/O) interface **38** operatively connected by a bus **39**. The I/O interface **38** is operatively connected to the user input **17** (for example in the form of a

keyboard and pointing device), display **29**, a network interface **40**, storage **41** in the form of hard disk storage and removable storage **42**.

Computer program code **43** is stored in the hard disk storage **38** and loaded into memory **37** for execution by the processor(s) **36** to provide the modules **14**, **19**, **24**. The computer program code **43** may be stored on and transferred from removable storage **42** or downloaded via the network interface **42** from a remote source (not shown).

The threat assessment system **11** generally has two modes of operation to meet different operational criteria.

In a "live mode", the activity predictor **14** periodically, for example daily, connects to the known threat database **10** (which is preferably continuously updated), retrieves the observed threat profile **9** and produces a new predicted activity **13**. The predicted activity **13** is fed back to the firewall **3**.

In an "analysis mode", a snapshot of the observed threat profile **9** is taken, predicted loss is assessed and a report produced.

Operation of the threat assessment system **11** will now be described in more detail.

The threat assessment system **11** uses an activity prediction process to extrapolate series of numbers in several places to find the next value in the series. In this example, weighted linear extrapolation is used, although other methods may be used, such as polynomial extrapolation.

Weighted linear extrapolation involves fitting a straight line y=mx+c through supplied data, finding values for the parameters m and c, and then using these parameters to find a value for y corresponding to a value of x beyond the range of that data.

A so-called "best fit" line is the one which is as close to as many of the supplied data points as possible. The closeness at a single point x_i is given by the residual r_i, namely:

$$r_i=y_i-(mx_i+c) \tag{1}$$

The overall quality of fit is given by the summed square of all the residuals, each weighted by the corresponding weighting factor:

$$S^1=\Sigma W_i(Y_i-(mx_i+c))^2 \tag{2}$$

i=1

The best fit line is found by minimizing S^1 with respect to m and c.

The minimum may be found by differentiating S^1 with respect to m and c.

$$\frac{\partial S^1}{\partial m} = -2\sum wx(y-(mx+c)) \tag{3}$$

$$\frac{\partial S^1}{\partial c} = -2\sum w(y-(mx+c)) \tag{4}$$

where the summations are from 1 to n for w, x and y.

The minimum is found where the differentials are 0, therefore:

$$\Sigma wx(y-(mx+c))=0 \tag{5}$$

$$\Sigma w(y-(mx+c))=0 \tag{6}$$

$$\Sigma wxy-m\Sigma wx^2-c\Sigma wx=0 \tag{7}$$

$$\Sigma wy-m\Sigma wx-c\Sigma w=0 \tag{8}$$

Equation (8) may be re-arranged to find c:

$$c=\frac{\sum wy-m\sum wx}{\sum w} \tag{9}$$

and, by substitution, m can be found:

$$m=\frac{\sum w\sum wxy-\sum wx\sum wy}{\sum w\sum wx2-(\sum wx)2} \tag{10}$$

Analogously,

$$m=\frac{\sum wy-c\sum w}{\sum wx} \tag{11}$$

$$\sum wxy-\frac{\sum wx2}{\sum wx}\left(\sum wy-c\sum w\right)-c\sum wx=0 \tag{12}$$

$$\sum wx\sum wxy-\sum wx2\sum wy=c\left(\left(\sum wx\right)2-\sum w\sum wx2\right) \tag{13}$$

$$c=-\sum wx\sum wxy+\sum wx2\sum wy\sum w\sum wx2-\left(\sum wx\right)2 \tag{14}$$

Given m and c from the formulae above, the series may be extrapolated to point n+1:

$$y_{n+1}=mx_{n+1}+c \tag{15}$$

Referring to FIGS. **1** to **5**, operation of the activity predictor **14** will be described in more detail.

The activity predictor **14** retrieves the observed threat data **9** from the observed threat database **10** (step S**1**) and sets about determining a time profile for each target, each time profile defined in terms of one of more time blocks and the number of successful threats expected in each time block (steps S**2** to S**13**).

In this example, threats are generally divided into three categories, namely malicious codes (e.g. viruses, Trojans and worms), attacks (e.g. hacking and denial-of-service attacks) and non-electronic forms of attack (e.g. fire and terrorist attacks). Fewer categories may be defined, for example, by excluding non-electronic forms of attack. However, additional categories or sub-categories may be defined or added, for example as new forms of threat emerge. It will be appreciated that these threats can be assessed in any order and may even be evaluated simultaneously, for example, if a multi-core computer system **35** is used.

Equations (9), (10) and (5) and/or (13), (14) and (15) above are used to predict the number of viruses (or other forms of malicious code) using input data specified in Table I below:

TABLE I

Item	Source	Symbol
Number of viruses seen by target t and period p	SNORT	$obs_{t/p}^{v}$
Number of viruses contracted by period p	User	$contr_p^{v}$
Number of new viruses worldwide by period p	www.wildlist.org	new_p^{v}

The number of viruses seen by a target in a period, $obs_{t/p}^{v}$, is obtained from the threat analyzer **6** running SNORT (or

other intrusion detection program). The number of viruses contracted in the given period of time, $contr_p^v$, is specified, via input device **17**, by the user. The number of new viruses worldwide in a period, new_p^v, is obtained from a virus (or other malicious software) information gathering organization, such as The Wildlist Organization (www.wildlist.org). The period, p, may be, for example, one week or four weeks. However, other periods, such n-weeks or n-months may be used, where n is positive integer.

The activity predictor **14** takes the number of viruses seen by a target for a given period of time, $obs_{t/p}^v$ and extrapolates the observed viruses to give the predicted number of viruses by target in the given period, $pred_p^v$ (step S**2**). The value for each target will be used to calculate the number of viruses expected to be contracted by the target.

The activity predictor **14** normalizes the predicted number of viruses by target in the given period, $pred_p^v$, to give a predicted fraction of viruses attacking each target, $frac\ pred_t^v$, by dividing the predicted number, $pred_t^v$ by the total number of new malicious codes which have been observed over the same period (step S**3**).

Steps S**2** and S**3** can be summarized as follows:

$$obs_{t/p}^v \xrightarrow{\text{extrapolate}} pred_t^v \xrightarrow{\text{normalise}} face\ pred_t^v$$

The activity predictor **14** divides the number of viruses contracted in each period, $contr_p^v$ by the number of new viruses worldwide in that period, new_p^v, to give the fraction of new viruses contracted in each period, $frac\ contr_p^v$ (step S**4**). The activity predictor **14** extrapolates this value to give the predicted fraction of new viruses that will be contracted, pred frac $contr^v$ (step S**5**).

Steps S**4** and S**5** can be summarized as follows:

$$\frac{contr_p^v}{new_p^v} = frac\ contr_p^v \xrightarrow{extrapolate} pred\ \ frac\ contr^v$$

The activity predictor **14** extrapolates the number of new viruses, new_p^v, to give a predicted number of new viruses (step S**6**), i.e.:

$$\frac{contr_p^v}{new_p^v} = frac\ contr_p^v \xrightarrow{extrapolate} pred\ \ frac\ contr^v$$

The activity predictor **14** multiplies the predicted fraction of new viruses that will be contracted, pred frac $contr^v$, by the number of new viruses, new_p^v, to give the predicted number of new viruses contracted, pred $contr^v$ (step S**7**), i.e.:

$$pred\ contr^v = pred\ frac\ contrv \times pred\ new^v$$

The activity predictor **14** multiplies the fraction of viruses for each target, $frac\ pred_t^v$, by the predicted number of viruses contracted, pred $contr^v$, to give the predicted number of viruses contracted by target, pred $contr_t^v$ (step S**8**), namely:

$$pred\ contr_t^v = frac\ pred_t^v \times pred\ contr^v$$

Finally, the activity predictor **14** copies the time and severity profile for predicted viruses contracted directly from $obs_{t/p}^v$ (step S**9**). For example, for each instance of a virus, the identity of the virus together with its time profile and severity profile is added to a table. This provides the predicted number of viruses contacted by target with time profile.

The activity predictor **14** uses equations (9), (10) and (15) and/or (13), (14) and (15) to carry out a similar process for predicting the number of hacking, denial-of-service attacks and other similar forms of attack, using input data specified in Table II below, using the following steps:

TABLE II

Item	Source	Symbol
Number of viruses seen by target t and period p	SNORT	$obs_{t/p}^{\alpha}$
Number of successful attacks by period p	User	$contr_p^{\alpha}$

The activity predictor **14** extrapolates observed attacks, $obs_{t/p}^{\alpha}$, to give predicted number of attacks by target, $pred_y^{\alpha}$ (step S**10**) and normalizes this to give predicted fraction of attacks attacking each target, $frac\ pred_t^{\alpha}$ (step S**11**).

Steps S**10** and S**11** can be summarized as follows:

$$obs_{t/p}^a \xrightarrow{\text{extrapolate}} pred_t^a \xrightarrow{\text{normalize}} face\ pred_t^a$$

The activity predictor **14** extrapolates the number of successful attacks to give the predicted number of successful attacks, pred $contr^{\alpha}$ (step S**12**), i.e.:

The activity predictor **14** multiplies the predicted number of successful attacks, pred $contr^{\alpha}$, by predicted fraction of attacks attacking each target, $frac\ pred_t^{\alpha}$, to give the predicted number of successful attacks by target (step S**13**), i.e.

$$pred\ contr_t^{\alpha} = frac\ pred_t^{\alpha} = pred\ contr^{\alpha}$$

The activity predictor **14** copies time and severity profile for predicted successful attacks directly from $obs_{t/p}^v$

For non-electronic threats, the user can provide the expected number of disabling events on the target with a given time profile (step S**14**).

The activity predictor **14** stores the expected number of malicious codes, attacks and disabling events in the predicted threat activity profile **13** (step S**15**).

Referring to FIGS. **1** to **4** and **6**, operation of the system risk calculator **19** will now be described in more detail.

For each threat, the risk calculator **19** carries out the following steps, namely steps S**16** to S**19**.

The risk calculator **19** determines downtime for a system category **33**, i.e. a target, based on the expected damage level for the successful threat (step S**16**). In this example, this is done using the value of the attribute "SeverityScore" using a look-up table giving a downtime for each SeverityScore for each system category. The risk calculator **19** can adjust the downtime, for example by taking into account mitigating factors, such as whether the system can operate in a safe mode and whether back-up systems are available (step S**17**). The risk calculator **19** multiplies each adjusted downtime by the frequency of occurrence of the successful threat to obtain a value of the total downtime for the threat (step S**18**). The risk calculator **19** then adds the downtime to an accumulated downtime for the system category (step S**19**).

For each system **30**, the risk calculator **19** adds up downtimes of dependencies of the system categories **33** on which the system **30** depends and, if appropriate, dependencies of the system categories on which those system dependencies depend (step S**29**). Circular dependencies among categories may be forbidden.

Referring to FIGS. **1** to **4** and **7**, operation of the predicted loss calculator **24** will now be described in more detail.

For each operational process, the predicted loss calculator **24** adds up predicted downtimes of the system categories on which it depends to determine a duration for which the process is unavailable (step S**21**). The predicted loss calculator **24** multiplies the duration by a value of the process to quantify the loss $\mathbf{12}_A, \mathbf{12}_B, \mathbf{12}_C, \mathbf{12}_D, \mathbf{12}_E, \ldots, \mathbf{12}_m$ for the process (step S**22**). For example, the value of the process may be a monetary value (e.g. given in pounds sterling per hour or dollars per day) and the loss may be value at risk for the process.

Once losses $\mathbf{12}_A$, $\mathbf{12}_B$, $\mathbf{12}_C$, $\mathbf{12}_D$, $\mathbf{12}_E$, . . . , $\mathbf{12}_m$ for each process have been determined, the predicted loss calculator **24** adds the losses $\mathbf{12}_A, \mathbf{12}_B, \mathbf{12}_C, \mathbf{12}_D, \mathbf{12}_E, \ldots, \mathbf{12}_m$, for all the processes to obtain a loss to the organization (step S**23**).

The loss $\mathbf{12}_A, \mathbf{12}_B, \mathbf{12}_C, \mathbf{12}_D, \mathbf{12}_E, \ldots, \mathbf{12}_m$, for each process and the loss $\mathbf{12}_{SUM}$, to the organization can be stored in database **28** and/or exported. As explained earlier, some or all of the losses $\mathbf{12}_A, \mathbf{12}_B, \mathbf{12}_C, \mathbf{12}_D, \mathbf{12}_E, \ldots, \mathbf{12}_m, \mathbf{12}_{SUM}$, can be displayed, for example as a bar chart, on display device **29**.

It will be appreciated that many modifications may be made to the embodiments hereinbefore described.

What is claimed is:

1. Apparatus for assessing and valuing computer network threats, the threats including at least one electronic threat, the computer network comprising a plurality of IT systems and a plurality of business processes operating on the plurality of IT systems, the apparatus comprising at least one processor and a memory coupled to the processor, the memory storing instructions executable by the processor that cause the processor to:

predict future threat activity based on past observed threat activity including, at least one electronic threat, to receive observed threat data from a database, to extrapolate future event frequency and to produce a profile of predicted threat activity, wherein the observed threat data includes observed threats and, for each observed threat, one or more targets for the observed threat and a severity score for each target;

determine expected downtime of each system of the plurality of IT systems in dependence upon said predicted threat activity including the severity scores and extrapolated future event frequency;

determine the financial loss for each of the plurality of business processes dependent on the downtimes of the IT systems, and;

add the financial losses for the plurality of business processes so as to obtain a combined financial loss arising from the threat activity.

2. The apparatus according to claim **1**, wherein the instructions comprise:

a first module configured to determine the predicted threat activity including, at least one electronic threat, to receive observed threat data from a database, to extrapolate future event frequency and to produce a profile of predicted threat activity, wherein the observed threat data includes observed threats and, for each observed threat, one or more targets for the observed threat and a severity score for each target;

a second module configured to determine the expected downtime of each IT system of the plurality of IT systems in dependence upon said predicted threat activity including the severity scores and extrapolated future event frequency and;

a third module configured to determine the financial loss for each of a plurality of business processes.

3. The apparatus according to claim **2**, wherein the third module is configured to add the financial losses for the plurality of business processes.

4. The apparatus according to claim **1**, wherein the apparatus is further configured to store at least one of the financial losses and the combined financial loss in a storage device.

5. The apparatus according to claim **1**, wherein the apparatus is further configured to output the financial losses and the combined financial loss to other apparatus comprising at least one processor and a memory coupled to the processor, the memory storing instructions being executable by the processor.

6. The apparatus according to claim **1**, wherein the apparatus is configured to display at least one of the financial losses and the combined financial loss on a display device.

7. The apparatus according to claim **1**, further configured to output the predicted future event activity to a firewall.

8. The apparatus according to claim **1**, further configured to output the profile of predicted threat activity to a firewall.

9. The apparatus according to claim **1**, wherein the observed list of threats includes, for each threat, information identifying at least one system.

10. The apparatus according to claim **1**, wherein the observed list of threats includes, for each threat, information identifying frequency of occurrence of the threat.

11. The apparatus according to claim **10**, wherein the frequency of occurrence of the threat includes at least one period of time and corresponding frequency of occurrence for the at least one period of time.

12. The apparatus according to claim **1** wherein the plurality of IT systems include a plurality of software systems.

13. A method of assessing and valuing computer network threats, the threats including at least one electronic threat, the network comprising a plurality of IT systems wherein a plurality of business processes operate on the plurality of IT systems the method comprising, by using at least one computer processor:

predicting threat activity based on past observed activity including, for at least one electronic threat, to receive observed threat data from a database, to extrapolate future event frequency and to produce a profile of predicted threat activity, wherein the observed threat data includes observed threats and, for each observed threat, one or more targets for the observed threat and a severity score for each target;

determining expected downtime of the plurality of IT systems in dependence upon said predicted threat activity including the severity scores and extrapolated future event frequency;

determining the financial loss for the plurality of business processes dependent on the downtimes of the IT systems;

adding the financial losses for the plurality of business processes to obtain a combined financial loss arising from the threat activity.

14. The method according to claim **13**, further comprising;

storing at least one of the financial losses and the combined financial loss in a storage device.

15. The method according to claim **13**, further comprising;

displaying at least one of the financial losses and the combined financial loss on a display device.

16. A non-transitory computer readable medium storing a computer program which when executed by a computer system, causes the computer system to perform a method of assessing and valuing computer network threats, the threats including at least one electronic threat, the computer network comprising a plurality of IT systems wherein a plurality of business processes operate on the plurality of IT systems, the method comprising:

predicting threat activity based on past observed activity including, at least one electronic threat, to receive observed threat data from a database, to extrapolate future event frequency and to produce a profile of predicted threat activity, wherein the observed threat data includes observed threats and, for each observed threat, one or more targets for the observed threat and a severity score for each target;

determining expected downtime of each of the plurality of IT systems in dependence upon said predicted threat activity including the severity scores and extrapolated future event frequency;

determining the financial loss for the plurality of business processes dependent on the downtimes of the IT systems;

adding the financial losses for the plurality of business processes to obtain a combined financial loss arising from the threat activity.

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